

1        1. A dental composition for bonding an amalgam restorative to a dental  
2 substrate, comprising:

3                at least one polymerizable material;

4                at least one photoinitiator in an amount so that at least a portion of the  
5 polymerizable material remains at least partially unpolymerized when the dental  
6 composition is exposed to a quantity of radiant energy sufficient to initiate  
7 polymerization of the polymerizable material; and

8                at least one chemical initiator that causes further polymerization of the  
9 polymerizable material when the dental composition is in contact with an amalgam  
10 restorative.

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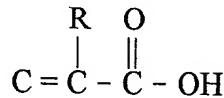
12        2. A dental composition as defined in claim 1, wherein the polymerizable  
13 material comprises at least one polymerizable promotor.

14

15        3. A dental composition as defined in claim 2, wherein the polymerizable  
16 promotor comprises at least one of a monomer, oligomer or other prepolymer having at least  
17 one ethylenically unsaturated group and at least one carboxylic acid group.

18

19        4. A dental composition as defined in claim 2, wherein the polymerizable  
20 promotor comprises, or is an oligomer of, at least one monomer having the formula:

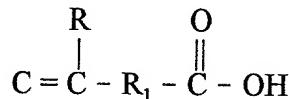


21                wherein R is a hydrogen radical, a methyl group, a saturated aliphatic radical, an  
22 unsaturated aliphatic radical, a halogen radical or a CN radical.

23

5. A dental composition as defined in claim 2, wherein the polymerizable  
promotor comprises at least one of methacrylic acid or acrylic acid.

4 6. A dental composition as defined in claim 2, wherein the polymerizable  
5 promotor comprises, or is an oligomer of, at least one monomer having the formula:



9 wherein R is a hydrogen radical, a methyl group, a saturated aliphatic radical, an  
10 unsaturated aliphatic radical, a halogen radical or a CN radical; and wherein R<sub>1</sub> is at least one  
11 oxygen radical, a saturated aliphatic radical, a saturated aliphatic radical interrupted by at  
12 least one oxygen or other polar radical, an unsaturated aliphatic radical, an unsaturated  
13 aliphatic radical interrupted by at least one oxygen or other polar radical, a homocyclic  
14 radical, a heterocyclic radical, a polymerizable moiety, or an aryl radical having four to six  
15 carbon atoms and a valency of n+1, with n being an integer of at least 6.

17        7. A dental composition as defined in claim 6, wherein the polymerizable  
18        promotor comprises at least one of 4-pentenoic acid, 6-heptenoic acid, or 2,2-dimethyl-4-  
19        pentenoic acid.

21        8. A dental composition as defined in claim 2, wherein the polymerizable  
22        promotor has a concentration in a range of about 0.5% to about 60% by weight of the dental  
23        composition.

5 9. A dental composition as defined in claim 2, wherein the polymerizable  
6 promotor has a concentration in a range of about 0.75% to about 50% by weight of the dental  
7 composition.

1       10. A dental composition as defined in claim 2, wherein the polymerizable  
2 promotor has a concentration in a range of about 1% to about 40% by weight of the dental  
3 composition.

4

5       11. A dental composition as defined in claim 1, wherein the polymerizable  
6 material comprises at least one polymerizable resin.

7

8       12. A dental composition as defined in claim 11, wherein the polymerizable resin  
9 comprises at least one of a hydrophilic resin having at least one hydroxy group or a  
10 hydrophobic resin.

11

12       13. A dental composition as defined in claim 11, wherein the polymerizable resin  
13 comprises at least one of hydroxyalkyl methacrylate, hydroxyalkyl acrylate, alkyl  
14 methacrylate or alkyl acrylate.

15

16       14. A dental composition as defined in claim 11, wherein the polymerizable resin  
17 comprises at least one of HEMA, Bis-GMA, glycerol dimethacrylate, methyl acrylate, methyl  
18 methacrylate, or triethylene glycol dimethacrylate.

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20       15. A dental composition as defined in claim 14, wherein the Bis-GMA has a  
21 concentration of less than about 4% by weight of the dental composition.

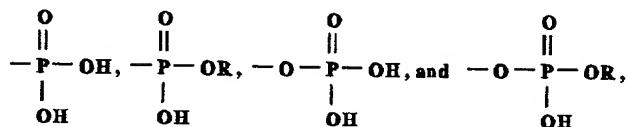
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23       16. A dental composition as defined in claim 14, wherein the Bis-GMA has a  
24 concentration of less than about 3% by weight of the dental composition.

25

1        17. A dental composition as defined in claim 14, wherein the Bis-GMA has a  
2 concentration of less than about 2% by weight of the dental composition.

4 18. A dental composition as defined in claim 11, wherein the polymerizable resin  
5 comprises at least one of the following groups:



10 wherein R is an alkyl.

12 19. A dental composition as defined in claim 11, wherein the polymerizable resin  
13 comprises at least one of bis glycerol methacrylate phosphate, bis 2-hydroxy ethyl  
14 methacrylate phosphate, phosphate ester of p-hydroxyphenyl methacrylamide, phosphate  
15 ester of 3-hydroxy propyl methacrylate, or phosphate ester of 4-hydroxy butyl methacrylate.

17 20. A dental composition as defined in claim 11, wherein the polymerizable resin  
18 has a concentration in a range of about 0.5% to about 60% by weight of the dental  
19 composition.

21        21. A dental composition as defined in claim 11, wherein the polymerizable resin  
22 has a concentration in a range of about 0.75% to about 50% by weight of the dental  
23 composition.

1       22. A dental composition as defined in claim 11, wherein the polymerizable resin  
2 has a concentration in a range of about 1% to about 40% by weight of the dental  
3 composition.

4

5       23. A dental composition as defined in claim 1, wherein the photoinitiator  
6 comprises at least one  $\alpha$ -diketone.

7

8       24. A dental composition as defined in claim 1, wherein the photoinitiator  
9 comprises at least one of camphoroquinone, benzoin methyl ether, benzophenone or 9,10-  
10 anthraquinone.

11

12       25. A dental composition as defined in claim 1, wherein the photoinitiator  
13 comprises at least one of phenyl bis(2,4,6-trimethyl benzoyl) phosphine oxide or 2-hydroxy-  
14 2-methyl-1-phenyl-1-propanone.

15

16       26. A dental composition as defined in claim 1, wherein the photoinitiator has a  
17 concentration less than an amount that is stoichiometrically required to cause complete  
18 polymerization of the polymerizable material if irradiated with an excess of radiant energy.

19

20       27. A dental composition as defined in claim 1, wherein the photoinitiator has a  
21 concentration in a range of about 0.001% to about 0.5% by weight of the dental composition.

22

23       28. A dental composition as defined in claim 1, wherein the photoinitiator has a  
24 concentration in a range of about 0.005% to about 0.2% by weight of the dental composition.

25

1        29. A dental composition as defined in claim 1, wherein the photoinitiator has a  
2 concentration in a range of about 0.008% to about 0.08% by weight of the dental  
3 composition.

4

5        30. A dental composition as defined in claim 1, wherein the chemical initiator  
6 comprises at least one peroxide.

7

8        31. A dental composition as defined in claim 30, wherein the chemical initiator  
9 comprises benzoyl peroxide.

10

11        32. A dental composition as defined in claim 30, wherein the chemical initiator  
12 comprises at least one of 2-butanone peroxide, lauroyl peroxide or tert-butyl peroxide.

13

14        33. A dental composition as defined in claim 1, wherein the chemical initiator has  
15 a concentration in a range of about 0.001% to about 5% by weight of the dental composition.

16

17        34. A dental composition as defined in claim 1, wherein the chemical initiator has  
18 a concentration in a range of about 0.01% to about 3% by weight of the dental composition.

19

20        35. A dental composition as defined in claim 1, wherein the chemical initiator has  
21 a concentration in a range from about 0.1% to about 2% of the dental composition.

22

23        36. A dental composition as defined in claim 1, further including at least one  
24 natural resin.

25

1       37. A dental composition as defined in claim 36, wherein the natural resin  
2 comprises at least one of a rosin, distillate, sap, oil, balsam, gum, an isolated constituent of  
3 one of the foregoing, a modification of one of the foregoing, or a synthetic replication of one  
4 of the foregoing.

5

6       38. A dental composition as defined in claim 36, wherein the natural resin  
7 comprises at least one of Canadian balsam, sandarac, mastic, pontianak, copal, manilla,  
8 peruvian, benzoin, elemi, opopanax, olibanum, styrax, benzoin siam, tolu, resinoid, tall, pine,  
9 or eugenol.

10

11       39. A dental composition as defined in claim 1, further including at least one  
12 particulate filler.

13

14       40. A dental composition as defined in claim 39, wherein the particulate filler  
15 comprises at least one glass.

16

17       41. A dental composition as defined in claim 40, wherein the glass comprises  
18 barium oxide glass.

19

20       42. A dental composition as defined in claim 41, wherein at least a portion of the  
21 barium oxide glass has been silanated.

22

23       43. A dental composition as defined in claim 39, wherein the particulate filler  
24 comprises at least one fluoride-releasing compound.

1       44. A dental composition as defined in claim 43, wherein the fluoride-releasing  
2 compound comprises at least one calcium fluorosilicate.

3  
4       45. A dental composition as defined in claim 1, further including at least one  
5 solvent.

6  
7       46. A dental composition as defined in claim 45, wherein the solvent comprises  
8 at least one of a hydrophilic hydrocarbon, hydrophobic hydrocarbon, or water

9  
10      47. A dental composition as defined in claim 45, wherein the solvent comprises  
11 at least one of ethanol or acetone.

12  
13      48. A dental composition as defined in claim 1, further including at least one  
14 polymerization inhibitor.

15  
16      49. A dental composition as defined in claim 1, wherein the dental composition,  
17 when used to bond an amalgam restorative to a dental substrate, yields a final bond strength  
18 between the amalgam restorative and dental substrate of at least about 15 MPa.

19  
20      50. A dental composition as defined in claim 1, wherein the dental composition,  
21 when used to bond an amalgam restorative to a dental substrate, yields a final bond strength  
22 between the amalgam restorative and dental substrate of at least about 20 MPa.

23  
24      51. A dental composition as defined in claim 1, wherein the dental composition,  
25 when used to bond an amalgam restorative to a dental substrate, yields a final bond strength  
26 between the amalgam restorative and dental substrate of at least about 25 MPa.

1       52. A dental composition as defined in claim 1, wherein the dental composition  
2 is a stable, one-part composition.

3

4       53. A dental composition as defined in claim 1, wherein the dental composition  
5 initially comprises multiple parts that are mixed together shortly before application to a  
6 dental substrate.

7

8       54. A dental composition as defined in claim 1, wherein the chemical initiator is  
9 initially stable when mixed with the photoinitiator and polymerizable material but  
10 decomposes when exposed to one or more metals contained in an amalgam restorative.

11

1        55. A dental composition for bonding an amalgam restorative to a dental  
2 substrate, comprising:

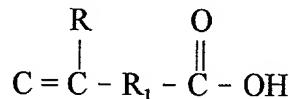
3 at least one polymerizable material;

4 at least one photoinitiator in an amount that is less than what is  
5 stoichiometrically required to cause complete polymerization of the polymerizable  
6 material if irradiated with an excess of radiant energy in the absence of oxygen; and

7 at least one chemical initiator that is initially stable when mixed with the  
8 photoinitiator and polymerizable material but that decomposes when exposed to one  
9 or more metals contained in an amalgam restorative in order to cause further  
10 polymerization of the polymerizable material when the dental composition comes  
11 into contact with the amalgam restorative.

13        56. A dental composition as defined in claim 55, wherein the polymerizable  
14 material comprises at least one polymerizable promotor that comprises at least one of a  
15 monomer, oligomer or other prepolymer having at least one ethylenically unsaturated group  
16 and at least one carboxylic acid group.

18 57. A dental composition as defined in claim 56, wherein the polymerizable  
19 promotor comprises, or is an oligomer of, at least one monomer having the formula:



23 wherein R is a hydrogen radical, a methyl group, a saturated aliphatic radical, an  
24 unsaturated aliphatic radical, a halogen radical or a CN radical; and wherein R<sub>1</sub> is a chemical  
25 bond, at least one an oxygen radical, a saturated aliphatic radical, a saturated aliphatic radical  
26 interrupted by at least one oxygen or other polar radical, an unsaturated aliphatic radical, an  
27 unsaturated aliphatic radical interrupted by at least one oxygen or other polar radical, a

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1 homocyclic radical, a heterocyclic radical, a polymerizable moiety, or an aryl radical having  
2 four to six carbon atoms and a valency of  $n+1$ , with  $n$  being an integer of at least 6.

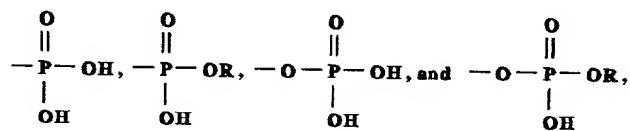
4 58. A dental composition as defined in claim 56, wherein the polymerizable  
5 promotor comprises at least one of methacrylic acid, acrylic acid, 4-pentenoic acid, 6-  
6 heptenoic acid, or 2,2-dimethyl-4-pentenoic acid.

8        59. A dental composition as defined in claim 55, wherein the polymerizable  
9 material comprises at least one polymerizable resin that comprises at least one of a  
10 hydrophilic resin having at least one hydroxy group or a hydrophobic resin

2 60. A dental composition as defined in claim 59, wherein the polymerizable resin  
3 comprises at least one of hydroxyalkyl methacrylate, hydroxyalkyl acrylate, alkyl  
4 methacrylate, alkyl acrylate, HEMA, Bis-GMA, glycerol dimethacrylate, methyl acrylate,  
5 methyl methacrylate, or triethylene glycol dimethacrylate.

7 61. A dental composition as defined in claim 60, wherein the Bis-GMA has a  
8 concentration of less than about 4% by weight of the dental composition.

62. A dental composition as defined in claim 59, wherein the polymerizable resin comprises at least one of the following groups:



wherein R is an alkyl.

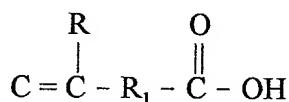
1       63. A dental composition for bonding an amalgam restorative to a dental  
2 substrate, comprising:

3               a polymerizable portion that includes at least one polymerizable promotor and  
4               at least one polymerizable resin;

5               at least one photoinitiator in an amount so that at least part of the  
6               polymerizable portion remains at least partially unpolymerized when the dental  
7               composition is exposed to a quantity of radiant energy sufficient to initiate  
8               polymerization of the polymerizable portion; and

9               at least one chemical initiator that causes further polymerization of the  
10               polymerizable portion when the dental composition is in contact with an amalgam  
11               restorative.

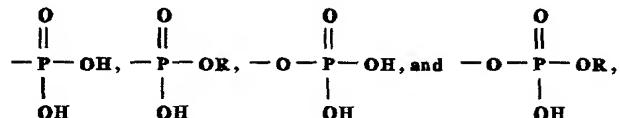
12  
13       64. A dental composition as defined in claim 63, wherein the polymerizable  
14               material comprises at least one polymerizable promotor that comprises, or is an oligomer of,  
15               at least one monomer having the formula:



19               wherein R is a hydrogen radical, a methyl group, a saturated aliphatic radical, an  
20               unsaturated aliphatic radical, a halogen radical or a CN radical; and wherein R<sub>1</sub> is a chemical  
21               bond, at least one an oxygen radical, a saturated aliphatic radical, a saturated aliphatic radical  
22               interrupted by at least one oxygen or other polar radical, an unsaturated aliphatic radical, an  
23               unsaturated aliphatic radical interrupted by at least one oxygen or other polar radical, a  
24               homocyclic radical, a heterocyclic radical, a polymerizable moiety, or an aryl radical having  
25               four to six carbon atoms and a valency of n+1, with n being an integer of at least 6.

1        65. A dental composition as defined in claim 63, wherein the polymerizable  
2 material comprises at least one polymerizable resin that comprises at least one of a  
3 hydrophilic resin having at least one hydroxy group or a hydrophobic resin.

5 66. A dental composition as defined in claim 65, wherein the polymerizable resin  
6 comprises at least one of the following groups:



wherein R is an alkyl.

1       67. A dental composition for bonding an amalgam restorative to a dental  
2       substrate, comprising:

3               at least one polymerizable material, with the proviso that the polymerizable  
4       material optionally includes Bis-GMA in a range from about 0% to about 4% by  
5       weight of the dental composition;

6               at least one photoinitiator in an amount that is less than what is  
7       stoichiometrically required to cause complete polymerization of the polymerizable  
8       material if irradiated with an excess of radiant energy in the absence of oxygen; and

9               at least one chemical initiator that is initially stable when mixed with the  
10      photoinitiator and polymerizable material but that decomposes when exposed to one  
11      or more metals contained in an amalgam restorative in order to cause further  
12      polymerization of the polymerizable material when the dental composition comes  
13      into contact with the amalgam restorative.

14  
15       68. A dental composition as defined in claim 67, wherein the Bis-GMA has a  
16      concentration of less than about 3% by weight of the dental composition.

17  
18       69. A dental composition as defined in claim 67, wherein the Bis-GMA has a  
19      concentration of less than about 2% by weight of the dental composition.